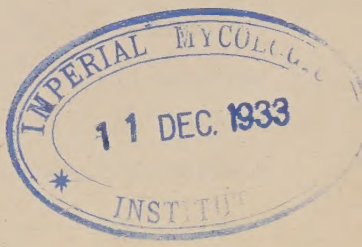
IMI

JUNE, 1933 TECHNICAL BULLETIN 49

VIRGINIA POLYTECHNIC INSTITUTE
Virginia Agricultural Experiment Station

Field and Laboratory Studies on Frenching of Tobacco



BY

G. M. SHEAR

BLACKSBURG, MONTGOMERY COUNTY, VIRGINIA

CONTENTS

PAGE

Introduction 3

Review of Literature 3

Field Results 5

Greenhouse Experiments 8

Discussion 13

Summary and Conclusions 14

Literature Cited 14

Field and Laboratory Studies on Frenching of Tobacco[1]

By G. M. Shear, *Assistant Plant Physiologist*

INTRODUCTION

Frenching is a non-infectious disease of tobacco that has been reported as occurring in most tobacco-growing regions of the world. It is quite erratic in its occurrence. It may affect only a few plants in a field or it may affect a large number of plants. It may occur in a field one year and not occur in that field again for a number of years. This apparent inconsistency of occurrence and the difficulty of reproducing it in the laboratory have given rise to much difference of opinion as to its cause or causes. When the disorder occurred extensively in experimental plots at Blacksburg, Virginia, during the summer of 1931, it was considered advisable to study the disease both in the field and under greenhouse conditions in order to substantiate or disprove the various opinions as to its cause or as to factors contributing to its development.

The symptoms of frenching are very characteristic and readily recognizable to anyone familiar with the disorder. Its first indications are mottling and thickening of the young leaves. The veins are dark green and the interveinal tissue varies in color from yellowish green to white. The plant may recover after this stage or the leaves may become more dwarfed and distorted while terminal growth ceases. At this stage many lateral buds commence growth, producing a large number of strap-shaped leaves. These narrow leaves may or may not be mottled. Examples of the different stages of frenching are shown in Figure 1.

REVIEW OF LITERATURE

There are two views as to the significance of the name frenching. Killebrew **(9)** says that "frenching" is derived from the French word friser (to curl), the term referring to the curled appearance of the leaves in the later stages of the disease. He does not say when or where this designation originated. Allard **(1)** refers to a letter by John Clayton to the Royal Society, May 12, 1688, stating that the term "frenching" or "frenched," is applied to sickly, spindling corn plants and peach trees as well as to tobacco plants, and that its origin dates back to the settlement of Maryland when the English settlers applied the term "Frenchmen" to weak spindling tobacco plants as a term of contempt. The latter reference is undoubtedly the most authentic information as to the origin and meaning of the term frenching. It can be seem from this statement that originally more than one disorder was included under the designation frenching.

By 1874, the term frenching was quite specific as is shown by a quotation from the United States Department of Agriculture Report for that year **(5)**. This report states, "Too much wet weather after the plant starts to grow, causing it to french as we term it; the leaf thickens, grows very narrow, dagger-shaped, frequently not broader than a case-knife and often as many as fifty leaves to a plant, all of them spread out on the ground. In this case the best plan is to pull the plant up, as it is worthless."

[1] Paper No. 82 from the Department of Botany and Plant Pathology. Edition of 2,500 copies.

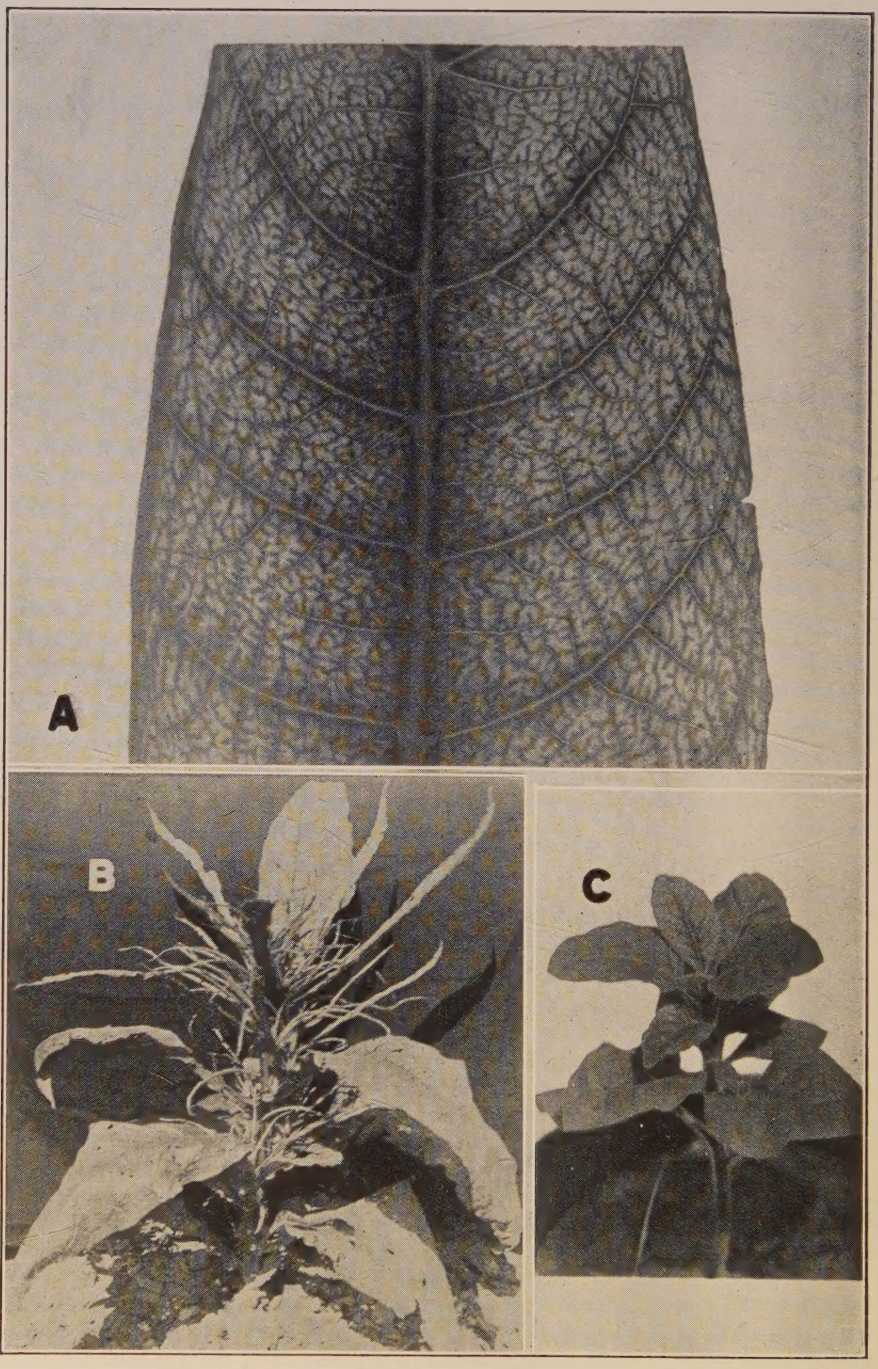


Fig. 1.—A, a section of a frenched leaf of tobacco showing the chlorotic condition of the interveinal tissue. B, a frenched plant of Burley tobacco showing numerous long, narrow leaves. C, a frenched plant of Turkish tobacco grown in a pot

The tenth census of the United States for the year 1880 (**9**) gives a brief summary of what was known about the disorder at that time. "Frenching occurs almost exclusively upon cold, stiff uplands having a close and stiff clay subsoil. During a wet season it is very prevalent upon clayey lands and is sometimes found upon sandy soils in small basins during excessively rainy weather. This disease renders the plant worthless when it has progressed to any considerable extent. The symptoms of the disease are first seen in the buds of the plant which become yellow in color. The leaves afterward become thick and fleshy, have a semi-transparent or honey-colored appearance and often curl around the edges downward, sometimes growing in long, narrow strips with ragged outlines. When cured the leaves are dull and lifeless in color and very brittle. No remedy for the disease has been found. It is sometimes arrested by close plowing, or by giving the plant a vigorous pull, so as to break the tap root, but the only preventive measure is to avoid planting upon a soil not properly underdrained either naturally or artificially." In this same article the author, in referring to mosaic, states that it is quite similar to frenching and is brought on by the same soil and weather conditions, showing that there was not a very clear distinction between these two diseases.

As recently as 1914, Allard (**1**) says that it has not been determined whether frenching is distinct from mosaic or only a somewhat different phase of this disease. Clinton (**4**) in the Connecticut Experiment Station Report for 1913, which was published in 1914 makes the distinction between the two diseases clear. He refers to frenching by the synonyms phyllodiniation and string leaves and says that it could not be transmitted by using juice from infected plants on young plants, and that plants inoculated with mosaic did not develop the symptoms of frenching, showing that it was not a severe form of mosaic. Wolf and Moss (**14**) and Garner (**6**) also state that frenching is noninfectious, although they do not indicate whether or not these results were obtained by them.

Johnson (**8**) in a bulletin on Tobacco Diseases and Their Control, which was published in 1924, summarizes what was known about frenching at that time as follows: "The actual cause of frenching is not yet known. The production of this disease at will has not been repeatedly accomplished. The disease is frequently found on soils exposed in one way or another to excessive water. This, together with its occurrence at times on portions of fields in poor tilth, indicates a relation to soil aeration. On the other hand, frenching seems to have considerable relation to soil fertility, or at least to a deficiency of certain fertilizing elements, but in combination with these factors certain weather conditions must apparently exist to bring about its expression."

In 1927 Valleau and Johnson (**12**) said that frenching was a nitrogen deficiency disease and Hopkins (**7**) of Southern Rhodesia supports their contention. Their data show that sufficient available nitrogen supplied to diseased plants generally causes recovery. More recent reports from Kentucky (**2, 3, 13**) state that this disorder in plants grown in the greenhouse is related to nutritional deficiencies (N, P, or K), and lime supply (pH).

FIELD RESULTS

Fertilizer plots planted with Wisconsin Root-Rot Resistant Burley tobacco were started on Hagerstown clay loam soil during 1931 at the Virginia Experiment Station Farm at Blacksburg. The area covered by the plots was several feet higher at one end of the field than at the other end. The plots were run in duplicate, one series on the lower portion of the field and the other on the higher portion. The fertilizer materials added to the various plots consisted of ammonium sulfate, superphosphate, potassium sulfate, sodium chloride, and stable manure. The amounts of fertilizer on an acre basis are shown in Figure 2. These plots were planned in connection with another project but were very well suited for obtaining information concerning frenching.

Frenching was first noticed August 12 and by August 28, it had become severe in the higher portion of the field. At this time a chart was made showing the location of the affected plants (Fig. 2). This chart covers the upper half of the field. By September 11, a very noticeable increase had occurred and this increase is also shown. It

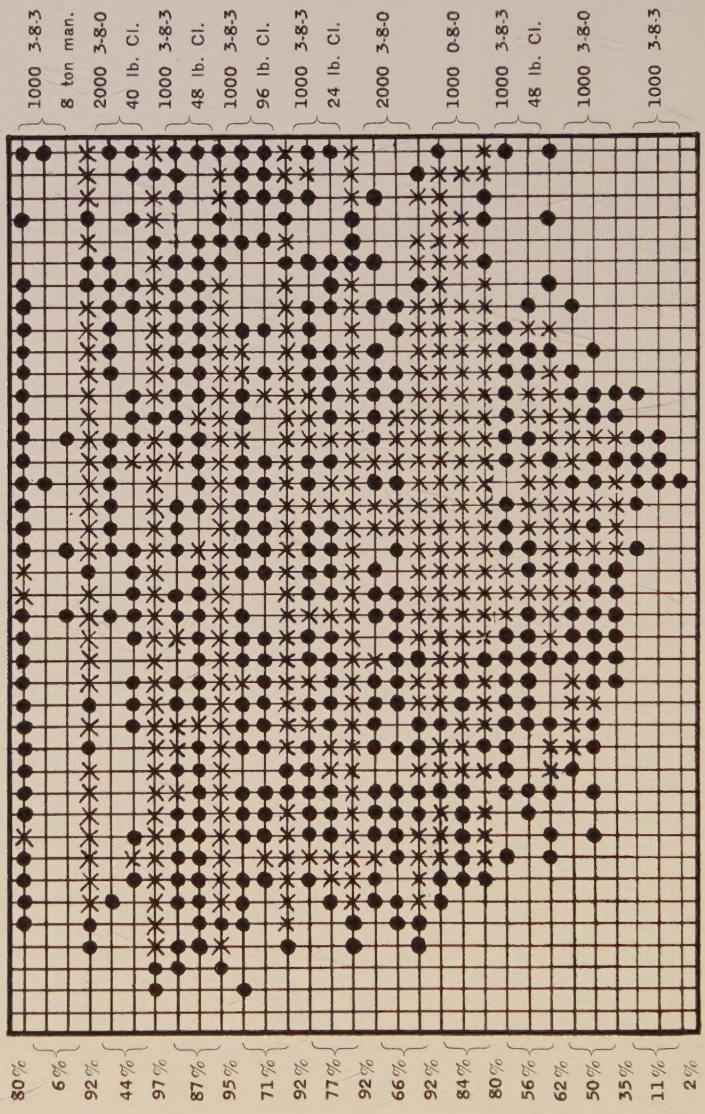


Fig. 2.—Chart showing location of frenched tobacco plants in field plots during 1931. Plants frenched on August 28 are represented by crosses, those frenching between that date and September 11 are represented by dots. Percentage of diseased plants shown at left and fertilizer treatments at right. The fertilizer treatments are expressed as pounds of N-P-K

will be noticed that regardless of the fertilizer treatments, the disease covered a fairly well defined area. Although the plots that received nitrogen fertilizer were slower in developing frenching, the percentage of affected plants in them was high at the second count which represents the maximum spread of the disorder in this section of the field. As compared with the adjoining check rows the plots receiving the most nitrogen showed

Fig. 3.—Frenching in plot receiving 2000 pounds 3-8-0 fertilizer. The plot consists of the two center rows with an unfertilized row on each side

a smaller percentage of affected plants (Fig. 3). Neither the potassium nor the phosphatic fertilizers showed any noticeable effect on the disorder. The plot that received a heavy application of stable manure in addition to the commercial fertilizer developed very few frenched plants, although the check rows on either side were severely affected. The stable manure besides furnishing extra available nitrates, improved the soil texture and greatly increased the microflora.

The pH of samples of the first six inches of soil next to diseased and healthy plants was determined at various places throughout the plots by means of a Youden Quinhydrone apparatus. The fertilizer plots which were consistently more acid than the check rows developed frenching more slowly, with the exception of the plot receiving only superphosphate where frenching developed at about the same rate and severity as in the adjoining check rows. By the end of the growing season frenching had developed in all fertilized plots in the affected section of the field. The range in pH next to affected plants was from 5.2 to 7.1.

The development and maintenance of frenching on the area under discussion shows a close correlation with the rainfall for the growing seasons of 1931 and 1932 (Table 1). Up to July 30, 1931, the rainfall since the tobacco had been planted was considerably below normal. On July 30, there was a rainfall of 3.1 inches which accounts for the surplus during that month. The rainfall was heavy during August, being quite evenly distributed during the month. In September the rainfall was very light. Frenching appeared two weeks after the heavy rainfall of July 30, and continued to spread and become more severe until the middle of September. On October 8, some of the less severely affected plants showed signs of recovery.

Table 1.—Monthly rainfall record for the growing seasons of 1931-1932

Month	1931		1932	
	Total precipitation Inches	*Departure from normal Inches*	*Total precipitation Inches*	*Departure from normal Inches*
May	5.11	+ 1.43	6.01	+ 2.33
June	2.76	— 1.56	6.29	+ 1.97
July	6.53	+ 1.50	2.85	— 2.18
August	7.28	+ 3.36	1.82	— 1.34
September	1.78	— 1.38	2.48	— 1.44

In 1932, tobacco plants were set in the same area in which the plants had been affected by frenching the preceding year. There was an excess of rainfall during both May and June and by the last week of June over half of the plants had developed frenching. During the rest of the season the rainfall was light and by the latter part of July frenching had commenced to disappear and was completely gone by the middle of August.

Various soil treatments carried out in the field in an attempt to correct the disorder were ineffective. Since one of the earliest recommendations for correcting frenching was to loosen the plant in the soil, one row of plants was lifted with a spading fork just enough to crack the soil around each plant. Chemical treatments were made, including salts of copper, iron, manganese, and nitrogen, and also sulfuric acid and lime to increase the pH range. In 1931 the treatments were made in September and from that time until frost there was so little rainfall that the plants did not grow enough to show any effect from the treatments. The next year treatments were made early in July but before they had had time to affect the frenching, all of the plants, both treated and untreated, recovered.

GREENHOUSE EXPERIMENTS

In order to carry on some experimental work in the greenhouse with this disorder, a supply of soil was obtained from the area in the field that produced frenching. The first few inches of soil from rows that received no fertilizer were used. Seedlings of Turkish tobacco transplanted into this soil developed frenching readily.

Several of the severely frenched plants from the field were transplanted into three-gallon crocks and placed in the greenhouse. The roots were disturbed as little as possible in transplanting and the soil was not packed very firmly in the crocks. When these plants were watered the soil settled and cracks developed in it. The new growth produced by these plants did not show signs of frenching.

A set of six frenched plants growing in crocks were watered heavily causing the soil to puddle and as the surface dried, deep cracks were produced. After this had occurred and following several waterings, the plants in these crocks recovered. From this time on the surface soil was removed before watering and replaced afterward. This prevented the formation of cracks and the frenching reappeared.

Difficulty was experienced in getting plants to french in porous clay flower pots since the moisture supply could not be maintained with any degree of uniformity. Coating the pots with paraffine or shellac rendered them temporarily water-proof but they had to be recoated before each new set of plants was grown in them. Four-inch glazed flower pots were found to be very satisfactory.

Frenched plants grown in four-inch pots recovered when they were tapped out of the pots as in transplanting and lightly replaced so as to leave an air space between the pot and the soil mass. These plants could be made to french again by pressing the soil down until it made contact with the side of the pot and then covering it with a wax seal.

In order to determine whether or not frenching could be corrected in this soil through the addition of nitrogen fertilizers, ammonium sulfate and sodium nitrate, were applied to frenched plants. These plants were grown in two-gallon crocks, one plant to a crock. Where ammonium sulfate was used it was applied at the rate of 11 grams per plant and sodium nitrate where used was applied at the rate of 17 grams per plant. Two weeks after these applications had been made the treated plants had recovered.

To test further the effect of available nitrates in this soil on the development of frenching two sets of six plants each were grown in four-inch pots. Several alternate layers of absorbent cotton and soil were placed in each pot of one set, while the other set received no cotton. Micro-organisms in the soil in decomposing the cotton, which is

practically pure cellulose, would reduce the available nitrates. The plants in the soil with cotton although developing frenching at the same time as the check plants, were shorter, more severely frenched and the lower leaves became yellow, a sign of nitrogen deficiency.

Frenched plants were placed in a moist chamber and half of them sprayed every other day with an 0.85 per cent solution of sodium nitrate, and on alternate days they were sprayed with water. The check plants were sprayed daily with water. These treatments were continued for three weeks, at the end of which time the plants sprayed with nitrate solution were still severely frenched. Since these plants were no greener than the check plants, they probably did not take up enough nitrate through the foliage to affect the plants.

Another method of supplying nitrate to frenched plants without applying it to the soil in which the plants were growing was tried. The pots were placed over beakers of water and the roots of the plants grew through the hole in the bottom of the pot

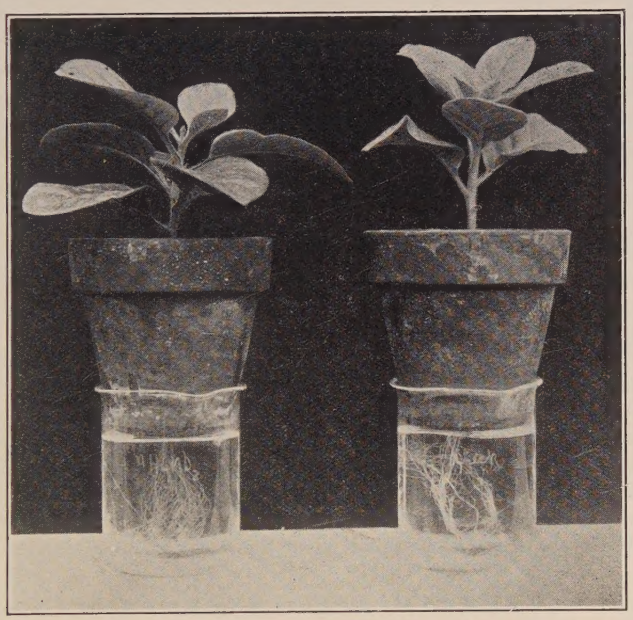


Fig. 4.—Plants with roots growing in beakers of nitrate solution and water

into the water in the beaker below (Fig. 4). When good root systems had developed beneath the pots some of the beakers were filled with a 0.20 per cent solution of ammonium nitrate while others continued to receive only water. The solutions were renewed every three days for a month but at the end of this time the plants that had received the nitrate although larger and darker green than the check plants were still frenched. By applying nitrate at the same rate to the soil in which the plants were growing, frenching was corrected in two weeks.

Different methods of partially sterilizing "frenching soil" were tried to see if they would have a different effect on the development of frenching. Soil in shallow pans was heated in an autoclave for fifteen minutes at from 15 to 18 pounds pressure. Soil in shallow pans was placed in a vacuum desiccator with a container of chloroform on the

top shelf after which the desiccator was partially evacuated to facilitate a more thorough distribution of the chloroform fumes. The soil was kept under these conditions for four days, the chloroform being renewed after two days. Formaldehyde dust was mixed with some soil at the rate of one ounce to a gallon of soil, which is the rate recommended for the control of certain soil-borne diseases. Plants were not put in this soil for several days to allow time for the formaldehyde to evaporate.

Plants grown in the chloroformed soil and in the steamed soil did not develop frenching while those in the formaldehyde-treated soil frenched at about the same time as check plants in untreated soil. Both the chloroforming and steaming killed the weed seed while the formaldehyde did not. The plants in the formaldehyde-treated soil were greener and larger than the checks but smaller than those receiving the other treatments. Another lot of soil that was chloroformed by the method just described except that the soil was in deeper layers produced frenching of plants grown in it. The treatment of this soil did not kill the weed seeds.

The factors that had been found to facilitate frenching in the soil studied, such as excess moisture or lack of aeration and a deficiency of nitrates, were combined in a series of water cultures. On January 11, 1932, fourteen Turkish tobacco plants were placed in quart jars of complete nutrient solution and were aerated daily. On January 20 these plants were divided into four lots. Six were aerated daily, three of them receiving a complete nutrient solution and three receiving a nutrient solution deficient in nitrates. Eight plants were not aerated, four receiving a complete nutrient solution and four receiving a solution deficient in nitrates. The nutrient solutions were renewed three times. When the experiment was discontinued March 10 no symptoms of frenching had developed. There was no appreciable difference between the aerated and unaerated plants receiving the same nutrient solution. The plants receiving the nutrient solution deficient in nitrates were about half the size of those receiving the complete solution.

Since Valleau and Johnson **(13)** state that frenching occurs at a pH of 6.0 and above it seemed desirable to determine the range of pH in which frenching would occur in this soil. The buffer curve of this soil was obtained and from it the amount of acid and base necessary to give intervals of 0.5 pH were determined. The range desired was from pH 5.0 to pH 8.0. The amount necessary to adjust the pH of 3000 grams of soil for each step in this range was mixed thoroughly with that amount of soil. The soil was kept moist and mixed several times and after standing ten days the pH of each lot was determined and the range actually obtained is shown in Table 2. The soil was made acid with hydrochloric acid and alkaline with sodium hydroxide. The two bases were used to see if the two materials would have different effects on the development of frenching.

Six plants were placed in soil of each pH on April 19, 1933, and by May 16, frenching had developed in three sets of plants. The progress of the frenching is shown in Table 2. After the plants had developed frenching, the soil from each set was mixed and the pH determined by Snyder's **(11)** modification of the hydrogen electrode method, which is the most accurate method yet devised for determining the pH of soils. These values are given in the last column of Table 2 and are the values considered in discussing these results.

Frenching developed most rapidly between pH 7.0 and 7.55. Due to a shifting of the pH toward neutrality the range was not as great as had been originally planned; therefore, the limits of acidity and alkalinity between which frenching occurs were not obtained. There was a rapid decline in the rate of development of frenching as the pH increased above 7.55. On the acid side this decrease was more gradual. No comparison could be made between the sodium and calcium hydroxides since the range between the two calcium treatments was so small.

Table 2.—Soil reaction and its effect on the rate of frenching

Reagent used	pH at beginning of experiment	Number of frenched plants												pH at end of experiment
		May 16	May 17	May 19	May 20	May 21	May 22	May 23	May 24	May 25	May 29	May 30	June 1	
HCl	5.20							3	5	5	6	6	6	5.80
HCl	5.45					3	4	6	6	6	6	6	6	5.95
HCl	6.10			3	6	6	6	6	6	6	6	6	6	6.56
HCl	6.65		3	5	6	6	6	6	6	6	6	6	6	7.07
NaOH	6.95	5	6	6	6	6	6	6	6	6	6	6	6	7.37
$Ca(OH)_2$	7.50	3	5	6	6	6	6	6	6	6	6	6	6	7.54
$Ca(OH)_2$	7.80	4	6	6	6	6	6	6	6	6	6	6	6	7.55
NaOH	7.50				1	3	4	6	6	6	6	6	6	7.60
NaOH	7.90									1	3	4	5	7.92

An experiment was set up on February 16, 1933, to determine whether frenching could be induced in sand cultures of tobacco plants watered with the leachings of the soil that produced frenching. Eight plants were set in six-inch shellacked pots of fine white sand. This sand had been used before and contained enough nutrients to produce a very limited growth. The holes in the bottom of the pots were partially stoppered with corks so as to retain the sand and yet allow excess water to escape. The surface of the sand in each pot was covered with a mixture of paraffine and petroleum jelly so that a high moisture content could be maintained in the sand. The plants received an excess of water twice a week, which amounted to approximately 100 cubic centimeters per watering. Four of the plants received only distilled water, while the other four received water that had passed through "frenching soil." The soil was contained in two-gallon crocks, one crock to two plants (Fig. 5). The crocks were kept covered with pans to prevent the soil from drying between waterings.

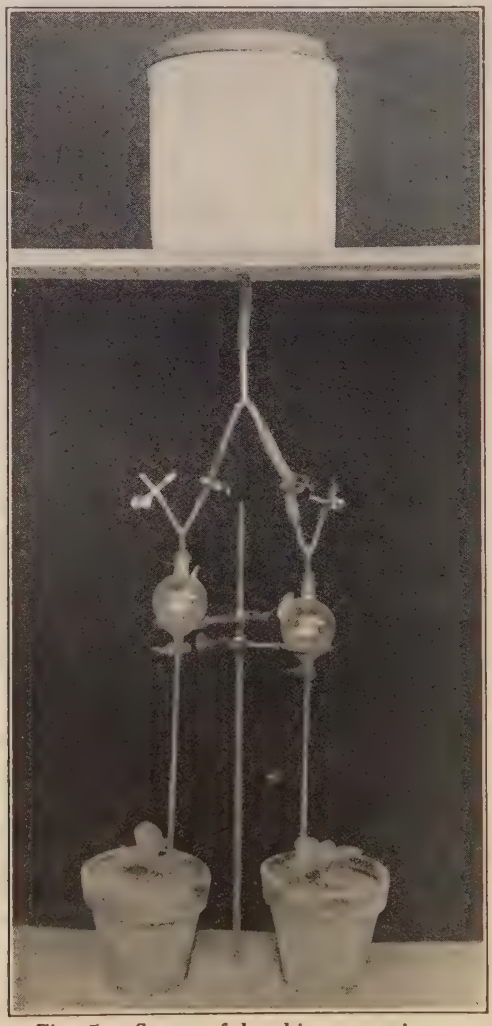


Fig. 5.—Setup of leaching experiment

The first signs of frenching showed up on March 13, on one of the plants watered with the leachings. On March 27, the other plant receiving leachings from the same crock of soil developed the disorder. The water passing through the other crock did not seem to be percolating through the soil very well; most of it ran down next to the side of the crock. Several holes were punched in the soil to give a more thorough leaching and by April 17 the plants receiving leachings from this crock of soil were both frenched. At the time this experiment was discontinued, April 25, none of the plants watered with distilled water had developed frenching.

DISCUSSION

It has been claimed that frenching could be corrected in different soils by the addition of nitrogen, phosphate, potassium, calcium and manganese salts. If this is so, it probably helps to explain the variations in the results obtained by different investigators through the use of unlike soils in experimenting on this disease. Since only one soil was used in the experiments reported here, it does not seem advisable to generalize too much on the results of this work. The author believes that although the factors contributing to the development of frenching may vary under different conditions these factors all tend to contribute to a single external underlying cause.

From both field and greenhouse results, poor soil aeration and an excess of soil moisture appear to be factors contributing to the development of frenching in the soil studied. These results comply favorably with the views expressed by many of those who have written about frenching (**5**, **8**, **9**, **14**). Valleau and Johnson (**12**) cite instances where excess soil moisture apparently was not a contributing factor in producing the disorder.

The amount of nitrogen fertilizer applied to some of the field plots should have been more than twice the quantity necessary to mature a crop of tobacco. Since it was applied as ammonium sulfate it would be necessary for it to be converted to nitrate before becoming available to the tobacco plants. Under unfavorable soil conditions for nitrification it is possible that it was not made available as rapidly as necessary to control frenching. Frenching in this same soil could be corrected through heavy applications of nitrogenous fertilizers.

Although Valleau and Johnson (**12**) corrected frenching by supplying nitrates to the plant without applying them to the soil in which the plant was growing, the results reported in this paper failed to show that this could be accomplished. It is possible that the method used by the above workers in obtaining these results partially isolated the top of the plant where the nitrate was supplied, from the lower section of the plant, thus stimulating growth in the top and causing it to function as a separate unit. These results as well as the results of the water-culture experiments where the different conditions influencing the production of frenching were combined show that the cause of this disorder is a condition inherent in the soil on which it is produced. All of the factors studied have many complex effects on the soil, both its organic and inorganic constituents.

Both Valleau and Johnson (**12**) as well as Hopkins (**7**) have expressed the view that frenching is a deficiency disease. In correspondence from F. A. Wolf in 1932, he states that he has been unable to determine whether it is the result of a deficiency or a toxicity. McMurtrey (**10**) says that it resembles the effects produced by thallium toxicity in tobacco, although it is not identical. The leaching experiment reported here shows that frenching can be produced in sand cultures by watering the plants with leachings from a soil that produces the disease. This indicates that frenching is the result of some material in the soil that is toxic to tobacco plants.

SUMMARY AND CONCLUSIONS

Frenching in the field developed in a well defined area regardless of fertilizer treatments. Within this area, plots receiving stable manure as well as plots receiving ammonium sulfate showed a smaller percentage of affected plants than adjoining unfertilized plots. Potassium sulfate and superphosphate had no apparent effect on the disease. The development of frenching in successive years on this area corresponded to periods of heavy rainfall.

Under greenhouse conditions frenching could be corrected by the addition of nitrogenous fertilizers to the soil or by the provision of conditions favorable for soil aeration. The addition of absorbent cotton to the soil increased the severity of the disorder.

Frenching could not be corrected by spraying the foliage of diseased plants with nitrate solution or by supplying the nitrates to roots growing beneath the pots of soil in which the plants were growing.

The disease could not be induced in water cultures either through a deficiency of nitrates or a lack of aeration, or by a combination of the two conditions.

Partial sterilization of the soil which produced frenched plants was effective in preventing the disorder where the treatment was severe enough to kill weed seed in the soil.

Frenching developed in soil having a range of pH from 5.8 to 7.9. It developed most rapidly between 7.0 and 7.5, decreasing quickly above this range and more gradually as the acidity increased.

Frenching was produced in sand cultures that were watered with the solution leached from soil that produced frenching. This indicates that frenching is a toxicity disease as opposed to the more generally expressed view that it is a deficiency disease.

LITERATURE CITED

(1) Allard, H. A.
1914. The mosaic disease of tobacco. U. S. Dept. of Agriculture Bulletin 40, 33 p.

(2) Annual Report.
1930. Kentucky Agricultural Experiment Station Report 43, pt. 1, 23-24.

(3) Annual Report.
1931. Kentucky Agricultural Experiment Station Report 44, 21-22.

(4) Clinton, G. P.
1914. Report of the botanist for 1913. Conn. Agr. Exp. Sta. Rept. 38, 27-29.

(5) Dodge, J. R.
1875. Report of the statistician. U. S. Dept. Agr. Rept. for 1874, 58.

(6) Garner, W. W.
1922. Tobacco culture. U. S. Dept. of Agric. Farmers' Bul. 571, 24 p.

(7) Hopkins, J. C. F.
1930. Field control of frenching in tobacco. Rhodesia Agr. Jour. 27 (6), 581-586.

(8) Johnson, James.
1924. Tobacco diseases and their control. U. S. Dept. Agr. Bul. 1356, 56 p.

(9) Killebrew, J. B.
1880. Report on the culture and curing of tobacco in the United States. Tenth Census of U. S. 3, 262.

(10) McMurtrey, J. E., Jr.
1932. Effect of thallium on growth of tobacco plants. Science N. S. 76 (1960), 86.

(11) Snyder, E. F.
1928. Methods for determining the hydrogen-ion concentration of soils. U. S. Dept. Agr. Circ. 56, 29 p.

(12) Valleau, W. D., and Johnson, E. M.
1927. Tobacco frenching—a nitrogen deficiency disease. Ky. Agr. Exp. Sta. Bul. 281, 180-253.

(13) ———————.
1932. Tobacco diseases in Kentucky. Ky. Agr. Exp. Sta. Bul. 328, 11-154.

(14) Wolf, F. A., and Moss, E. G.
1919. Diseases of flue-cured tobacco. The Bulletin North Carolina Dept. Agr. 40 (12), 45 p.